settle down at one-fifth of the initial rate. Therefore the *effective* concentration would be equivalent to 220 pellets to treat 330 litres/day, or 0.67 pellet per litre-day. From the first experiment, this concentration should kill newly added snails in about 5 days.

In practice it was found that it was necessary to replace the snails at the rate of 10 every second day, indicating a 100% mortality in 4 days. The difference may have been due to the differences in temperatures at which the experiments were carried out; the third experiment was done at 19°C–20°C (the tap-water temperature) while the first and second experiments were at 25°C. Also, tap water was used in the third experiment whereas boiled tap water was used in the first and second. The results indicate that the pellets released molluscicide into the water continuously for at least 82 days. The rate of release dropped very quickly from its initial level and after about 8 days settled down to an almost constant release rate of about 20% of that seen on the first day.

The contributions of the individual molluscicides tributyltin oxide and niclosamide to the snail mortality in these trials is unknown. However, Goll (personal communication) found pellets 633A, which contain niclosamide only, to be inactive when given only a 24-h exposure. This would suggest that tributyltin oxide is the active ingredient in the pellets.

A possible practical use of the pellet formulation is as a chemical barrier against repopulation after the existing population have been killed by a single molluscicide application. Several weeks afterwards, the pellets could be suspended in the water to prevent repopulation.

The number of pellets required for this operation is difficult to gauge but from the above work where 0.67 *effective* pellet per litre killed snails in 4 days and from the results in the first experiment where 1 pellet/8 litres killed snails in 216 hours, it appears to be a very low dose, perhaps 1 pellet/4 litres or lower sufficing as a chemical barrier. At 1 pellet/4 litres in flowing water this would require about 29 kg of pellets per ft^3/s of water, or a little over 1 kg per litre/s, for perhaps 5 snail-free years.

* * *

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Biological Control of *Biomphalaria glabrata* by *Marisa cornuarietis* in Irrigation Ponds in Puerto Rico

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Despite the increasing interest in *Marisa cornuarietis* (Gray) as an agent for biological control of schistosome-bearing snails, there has been a need for large-scale field tests from which to develop cost-efficiency data for this control method. As a result, a gap has been created between the state of development of chemical and of biological control techniques. This gap has prevented the integrated use of biological and chemical agents for the control of schistosomiasis. During 1955 the Puerto Rico Department of Health, in its pilot project for control of schistosomiasis mansoni, was faced with the high cost of eliminating *Biomphalaria glabrata*, the intermediate molluscan host, with chemical toxicants in artificial impoundments. Thus, during 1956 it was decided to implement a study on biological control in 111 irrigation ponds of the Guayama–Arroyo project using *M. cornuarietis* as the control agent.

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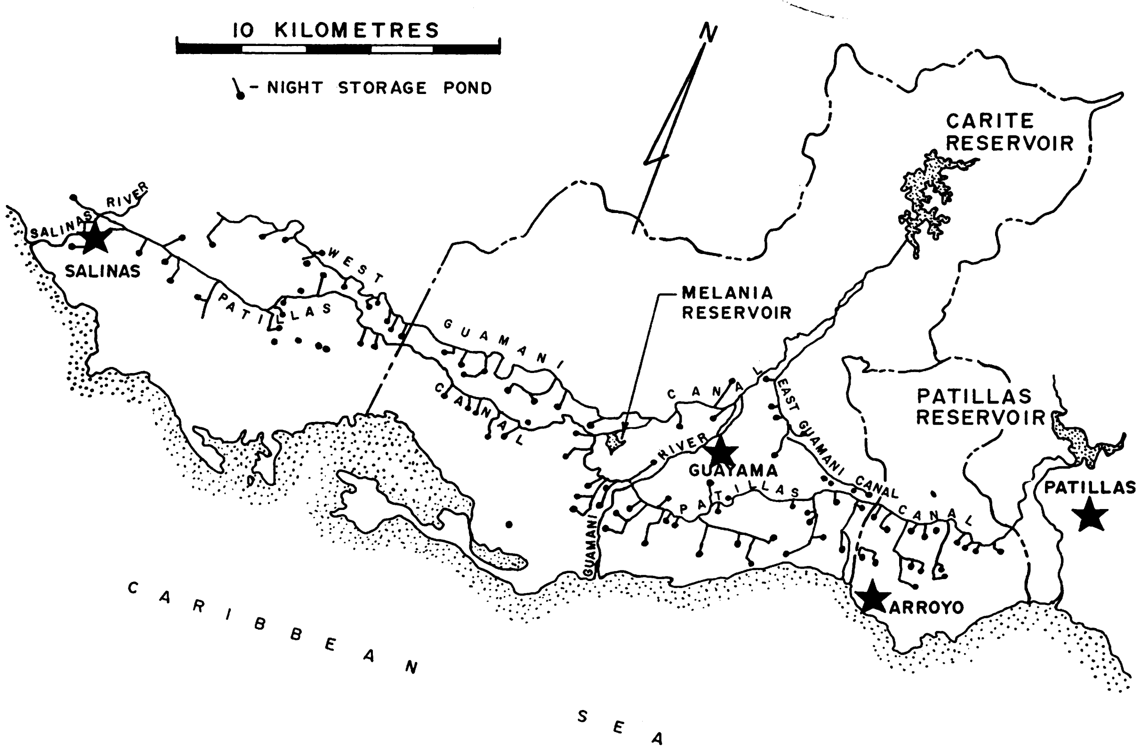
FIG. 1
GUAYAMA-SALINAS IRRIGATION SYSTEM, SHOWING LOCATION OF NIGHT STORAGE PONDS AND MAIN IRRIGATION CANALS



The purpose of this study is to examine the effect of artificially planted *M. cornuarietis* upon naturally occurring *B. glabrata* in 111 ponds and on *B. glabrata* carried into the ponds from the supply canals. An additional aim is to compare cost-efficiency data for this control technique with data for chemical mollusciciding in adjacent watersheds.

Materials and methods

The night storage ponds are part of the irrigation system on the south coast of Puerto Rico. This system, constructed during 1914, consists of 2 reservoirs that distribute water to a cultivated strip between the towns of Patillas and Salinas.[b] Three main canals, Patillas (40 km long), Guamani West (25 km long), and Guamani East (6.4 km long), supplemented by water from 27 wells, irrigate 7183 ha of sugar cane (Fig. 1).

[b] Lucchetti, A. (1933) *Anuario de la Cámara de Comercio de Puerto Rico*, San Juan.

Water distribution is managed through numerous night-storage ponds to reduce labour for operating the irrigation system. The earth-banked ponds have an average area of 0.5 ha and a design water depth of approximately 2 m. About 2% of the total number of ponds are lined with concrete. The ponds are filled to capacity at night and are emptied by gravity flow to a depth of 30 cm–50 cm daily. Water is fed directly into field lateral canals from the ponds. Both bank-side and aquatic plants grow rapidly in these snail habitats and are removed when necessary either manually, mechanically, or chemically. Ponds seriously choked with vegetation are dried out and cleaned with bulldozers.

The initial group of *M. cornuarietis* snails was collected from sites near Rio Piedras, Puerto Rico, and planted in 3 irrigation ponds where the population development was checked every 2 months during 1956. Thereafter, snail populations were checked annually, using a standard long-handled sieve made with 3-mm mesh hardware cloth with a collecting

TABLE 1

SUMMARY OF THE CONTROL OF *BIOMPHALARIA GLABRATA* IN 111 IRRIGATION PONDS BY *MARISA CORNUARIETIS* IN THE GUAYAMA-ARROYO SCHISTOSOMIASIS CONTROL PROJECT, 1956-65

	Year of study								
	1956–57	1957–58	1958–59	1959–60	1960–61	1961–62	1962–63	1963–64	1964–65
No. of ponds with *B. glabrata*	111	111	94	67	27	10	13	0	3
No. of ponds with snails other than *M. cornuarietis* or *B. glabrata*	0	0	2	5	5	3	3	2	4
No. of ponds with water but with no snails of any species	0	0	0	1	1	12	11	3	1
No. of ponds temporarily dry	0	0	11	9	15	22	24	30	14
No. of ponds controlled by *M. cornuarietis* [a]	0	0	4	29	63	64	55	76	89
Total no. of ponds under study	111	111	111	111	111	111	111	111	111
No. of ponds with water	111	111	100	102	96	89	82	81	97
No. of ponds controlled by *M. cornuarietis*/No. of ponds with water	0/111	0/111	4/100	29/102	63/96	64/89	55/82	76/81	89/97
% of total no. of ponds with water controlled by *M. cornuarietis*	0	0	4	28	66	72	67	94	92
No. of new ponds seeded with *M. cornuarietis*	3	25	66	10	2	2	3	0	0
No. of ponds reseeded with *M. cornuarietis* [b]	0	19	21	28	41	22	23	34	41

[a] These are ponds which originally contained *B. glabrata*, but during the year observed the dominant species was *M. cornuarietis* and no *B. glabrata* were present. Some ponds contained other aquatic snails as well as *M. cornuarietis*.

[b] The criteria for reseeding of ponds was low population numbers of *M. cornuarietis* as determined by each annual snail survey with the long-handled sieve, and independent of population densities of other snail species.

area of 0.5 m^2. The sieve was used for estimations of population densities and for collecting *M. cornuarietis* suitable for seeding in other ponds. Dips were taken every 2 or 3 paces around each pond by the same crew for the period of study. From the original 3 ponds, *M. cornuarietis* were collected and seeded in 25 additional water units during 1957 and, in turn, these 25 units provided *M. cornuarietis* for 66 further units in 1958, 10 units in 1959, 2 units in 1960, 2 units in 1961, and finally, 3 units in 1963. Thus, a total of 111 units was stocked with *M. cornuarietis* from 1956 to 1963.

Results

The ampullarid snail began to displace *B. glabrata* in a significant number of ponds within 4 years of the first seedings. In 1959, 3 years after the programme began, *M. cornuarietis* had controlled only 4 ponds after 94 seedings and 40 reseedings involving 106 000 ampullarids. However, by 1960, *M. cornuarietis* had displaced the planorbid snail in 29 ponds and was proceeding to take over the others. In 1965, *B. glabrata* had been displaced in 89 out of 97 ponds (92%) still in operation. This effort required a total of 111 seedings and 229 reseedings, amounting to 179 700 *M. cornuarietis* (Tables 1 and 2; Fig. 1).

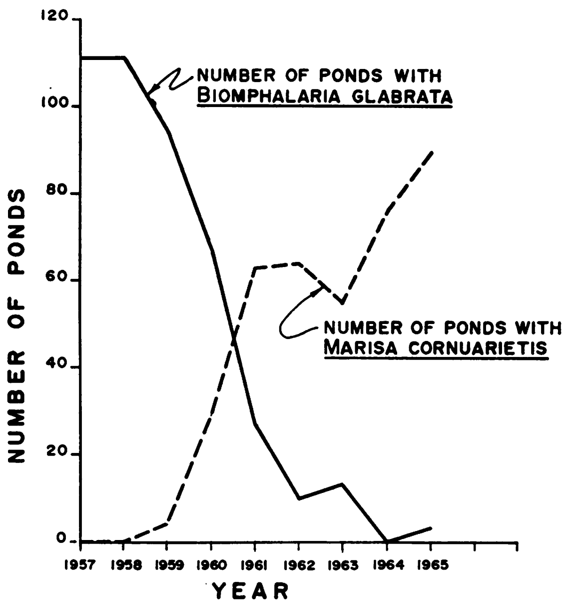
The total cost of planting and replanting *M. cornuarietis* in the 111 ponds was US $5467 over the 9 years. The yearly average cost was $607 or $5.47 per pond, as may be calculated from Table 2. These cost figures were obtained by multiplying the total number of ponds seeded and reseeded by the wages for 3 men working 5 hours per day and adding the estimated transport cost. The study was an integral part of the schistosomiasis control efforts within the Guayama–Arroyo project where routine mollusciciding with sodium pentachlorophenate (NaPCP) was performed in streams and swamps. Two to three days a month were allocated to the collection and seeding of *M. cornuarietis* snails for the period of study. Wages were calculated on the basis of $1.00 per hour for a 3-man crew

TABLE 2
COST ANALYSIS OF BIOLOGICAL CONTROL PROJECT IN 111 IRRIGATION PONDS IN PUERTO RICO, 1956–65

Year of study	No. of ponds newly seeded with *Marisa*	No. of ponds reseeded with *Marisa* [a]	Total no. of ponds seeded and reseeded with *Marisa*	Total no. of *Marisa* planted	Estimated transport cost (US$)	Estimated labour cost [b] (US$)
1956–57	3	0	3	3 000	3.24	45.00
1957–58	25	19	44	30 700	47.52	660.00
1958–59	66	21	87	72 300	93.96	1 305.00
1959–60	10	28	38	18 400	41.04	570.00
1960–61	2	41	43	14 300	46.44	645.00
1961–62	2	22	24	8 600	25.92	360.00
1962–63	3	23	26	9 900	28.08	390.00
1963–64	0	34	34	10 200	36.72	510.00
1964–65	0	41	41	12 300	44.28	615.00
Total	111	229	340	179 700	367.20	5 100.00

[a] Same as last row of Table 1.
[b] Obtained by multiplying figure in 4th column by wages for 3 men working 5 hours ($15.00).

FIG. 2
CONTROL OF *BIOMPHALARIA GLABRATA* IN IRRIGATION PONDS AFTER INTRODUCTION OF *MARISA CORNUARIETIS*



spending 5 hours working at collecting, transporting, and seeding *M. cornuarietis* in ponds. Transport costs were calculated on the basis of an 18-km average trip with one vehicle, operating at a cost of $0.06 per km. In terms of individual snails planted, the cost for each *M. cornuarietis* was $0.03 delivered in place. This technique required only the bare essentials in manpower and equipment, i.e., 3 unskilled labourers, 1 vehicle, buckets for transporting *M. cornuarietis*, and snail dippers. It did not require weirs, dispensing devices, handling of chemicals, power pumps, specialized control personnel, nor did it present other problems that are inherent in the chemical control of *B. glabrata*.

Discussion

Since its introduction around 1952 in Puerto Rico, *M. cornuarietis* has been studied thoroughly in the laboratory and under field conditions because of its observed effects on *B. glabrata* populations.[c-f] Field

[c] Ferguson, F. F. & Palmer, J. R. (1958) *Amer. J. trop. Med. Hyg.*, 7, 640-642.
[d] Ferguson, F. F., Oliver-Gonzalez, J. & Palmer, J. R. (1958) *Amer. J. trop. Med. Hyg.*, 7, 491-493.
[e] Oliver-Gonzalez, J., Bauman, P. M., & Benenson, A. S. (1956) *Amer. J. trop. Med. Hyg.*, 5, 290-296.
[f] Oliver-Gonzalez, J. & Ferguson, F. F. (1959) *Amer. J. trop. Med. Hyg.*, 8, 56-59.

studies have demonstrated the ability of *M. cornuarietis* to act as both predator and competitor of *B. glabrata*, the intermediate host of *Schistosoma mansoni* in Puerto Rico.[g, h] Under laboratory conditions, *M. cornuarietis* preys freely on immature and adult *B. glabrata* as well as on its egg masses.[i] Other disease-carrying snails such as *Lymnaea* and *Bulinus* are also affected in the same manner by *M. cornuarietis*.[j]

The average yearly cost for *M. cornuarietis* as the control agent of *B. glabrata* in the Guayama–Arroyo project, including all labour and transport but no overhead or supervision costs, was $607 to treat 555 000 m^3 of water. In 1955, one year prior to this biological control study, 1331 kg of NaPCP were used in the same project to treat 110 000 m^3 of water at a total cost, including overhead and supervision, of $8295, over 60 times as much as biological control per cubic metre of habitat.[k]

The operational cost of the control of *B. glabrata* in the adjoining Patillas project, where NaPCP was also used, was $9.70 per 100 m^3 of water treated at 10 ppm (Fig. 1).[l] By projecting the above figures, the operational cost, including overhead, would have been $54 000 for a single treatment of all the ponds with NaPCP.

Had ponds been treated with niclosamide ethanolamine salt (Bayluscide), the yearly expenditure would have been $6593 for a single treatment of all ponds at a concentration of 0.4 ppm. The above figure includes the cost of chemical ($24.22 per kg of active ingredient), labour ($1.00 per man-hour), and transport ($0.37 per pond). Overhead costs are not included. In contrast, the average annual cost for treating all ponds with *M. cornuarietis* was $607, as stated above.

Since this study was conducted without control ponds, it might be concluded that the disappearance of *B. glabrata* was due to other factors. This possibility will be examined in another report based upon a retrospective study, made in the field, of the current ability of a sample of the ponds to support *B. glabrata* in the absence of *M. cornuarietis*. However, it has already been established that *M. cornuarietis* controls *B. glabrata* in ordinary farm ponds.[e, g] The question remaining is whether the irrigation ponds are similar enough to the farm ponds. The primary difference is the water level fluctuations of the irrigation ponds, which makes reseeding necessary more frequently.

The possibility is very remote that the effects of weed-control operations and fluctuations in the water level of the ponds caused the disappearance of *B. glabrata*. Weed control and fluctuations in the pond levels are inherent in operating any irrigation system of this type, and they occurred from 1914 to 1957 without eliminating the populations of *B. glabrata*. Thus, it is difficult to believe that these routine happenings were responsible for the sudden disappearance of *B. glabrata*, coinciding precisely with the introduction of *Marisa*. However, these operational features may contribute in some way to the remarkable success of *Marisa* in dominating habitats and to the low cost of this biological method of control.

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The authors wish to express their gratitude to Mr Guillermo Colon Atilano, Chief Inspector of the Guayama–Arroyo schistosomiasis control project, and to his men for their faithful and diligent work which enabled this project to be accomplished.

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[g] Jobin, W. R.: manuscript to be published.

[h] Radke, M. G., Ritchie, L. S. & Ferguson, F. F. (1961) *Amer. J. trop. Med. Hyg.*, **10**, 370-373.

[i] Chernin, E., Michelson, E. H. & Augustine, D. L. (1956) *Amer. J. trop. Med. Hyg.*, **5**, 297-307.

[j] Demian, E. S. & Lutfy, R. G. (1966) *Oikos*, **17**, 212-230.

[k] Jobin, W. R., Ferguson, F. F. & Palmer, J. (1969) *Bull. Wld Hlth Org.* (in press).

[l] Palmer, J., Colon, A., Ferguson, F. F. & Jobin, W. R. (1969) *Publ. Hlth. Rep. (Wash.)* (in press).

Transliteration from Cyrillic characters

The " International System for the Transliteration of Cyrillic Characters ", set out in Recommendation ISO/R9-1954 (E) of the International Organization for Standardization, is normally used in the *Bulletin of the World Health Organization* for personal names, titles of publications, etc. However, papers accepted for publication may contain names transliterated differently, and if the original Cyrillic spelling is not recognizable inconsistencies may occur.

For convenience the transliteration from Russian according to ISO/R9 is given below:

Translittération des Caractères cyrilliques

Le « Système international pour la translittération des caractères cyrilliques » présenté dans la Recommandation ISO/R9-1954 (F) de l'Organisation internationale de Normalisation est généralement utilisé dans le *Bulletin de l'Organisation mondiale de la Santé* pour les noms de personnes, les titres de publications, etc. Cependant des articles acceptés pour publication peuvent contenir des noms translittérés différemment et si l'orthographe cyrillique originale n'est pas reconnaissable un manque d'uniformité peut s'ensuivre.

A toutes fins utiles, la translittération du russe selon la recommandation ISO/R9 est indiquée ci-après:

Cyrillic character Caractère cyrillique	Transliteration from Russian Translittération du russe	Examples and remarks Exemples et observations
А, а	a	Адрес = Adres
Б, б	b	Баба = Baba
В, в	v	Вы = Vy
Г, г	g	Глава = Glava Голова = Golova
Д, д	d	Да = Da
Е, е (ё) [1]	e (ë)	Ещё = Eščë
Ж, ж	ž	Журнал = Žurnal
З, з	z	Звезда = Zvezda
И, и	i	Или = Ili
Й, й	j	-ый, -ий, -ой = -yj, -ij, -oj
К, к	k	Как = Kak
Л, л	l	Любить = Ljubit'
М, м	m	Муж = Muž
Н, н	n	Нижний = Nižnij
О, о	o	Общество = Obščestvo
П, п	p	Первый = Pervyj
Р, р	r	Рыба = Ryba
С, с	s	Сестра = Sestra
Т, т	t	Товарищ = Tovarišč

Cyrillic character Caractère cyrillique	Transliteration from Russian Translittération du russe	Examples and remarks Exemples et observations
У, у	u	Утро = Utro
Ф, ф	f	Физика = Fizika
Х, х	h	Химический = Himičeskij
Ц, ц	c	Центральный = Central'nyj
Ч, ч	č	Часы = Časy
Ш, ш	š	Школа = Škola
Щ, щ	šč	Щека = Ščeka
(medial, médial) Ъ, ъ (final)	″or″ ″ou″ (Not transliterated. Non translittéré.)	In modern Russian, where ′ sometimes replaces medial ъ, transliteration is still ″. En russe moderne, où le ′ remplace quelquefois le ъ médial, la translittération reste ″.
Ы, ы	y	Был = Byl
Ь, ь	′or′ ′ou′	Маленький = Malen'kij
Э, э	e̊	Это = E̊to
Ю, ю	ju	Южный = Južnyj
Я, я	ja	Яйцо = Jajco

[1] Cyrillic ë to be transliterated by ë only when the diacritical appears in the original. Le ë cyrillique ne doit être translittéré par ë que lorsque la diacritique apparaît dans l'original.